A11101 986631

NAT'L INST OF STANDARDS & TECH R.I.C.

A11101986631

/Bureau of Standards journal of research
QC1 .U52 V4;129-182;1930 C.2 NBS-PUB-C 1

RP182

ENDURANCE PROPERTIES OF SOME SPECIAL RAIL STEELS

By John R. Freeman, Jr., and R. D. France

ABSTRACT

A series of tests have been carried out to determine the endurance properties of steel from heat-treated rail: Medium manganese rail, a zirconium-treated medium manganese rail, and a manganese molybdenum rail. Results are also given of some tests made on steel from a transverse fissured rail and an unfissured rail from the same heat that had been subjected to similar traffic. Heat treatment of rails was found to have markedly increased the endurance limit of the steel. Medium manganese rail steels were found, in general, to have a higher endurance limit than carbon rail steels. The manganese molybdenum rail steel had approximately the same endurance limit as the medium manganese rail. The steel in the fissured rail was found to have approximately the same endurance limit as steel from the unfissured rail.

CONTENTS

	Page
I. Introduction	851
II. Material studied	852
1. Medium manganese rail	852
2. Heat-treated rails	853
3. Manganese molybdenum rail	853
4. Zirconium-treated medium manganese rail	853
III. Test methods	853
IV. Results of tests	854
1. Hardness survey	854
2. Tensile tests	855
3. Endurance properties of medium manganese rails	858
4. Endurance properties of heat-treated rails	862
5. Endurance properties of manganese molybdenum rail steel	871
6. Endurance properties of a medium manganese rail steel treated with zirconium	871
V. Some further tests of transverse fissured rails	871
VI. Summary and conclusions	873

I. INTRODUCTION

The Bureau of Standards was requested by the special joint subcommittee of the Rail Manufacturers Technical Committee and the Rail Committee of the American Railway Engineering Association to determine the endurance properties of some special heat-treated rail steels and of the so-called "medium manganese rail" steels. The bureau was also requested by G. N. Eaton, of the Molybdenum Corporation of America, to determine the endurance properties of a special manganese molybdenum rail and by Dr. G. B. Waterhouse to make similar tests on a zirconium-treated medium manganese rail.

The proposed tests fitted in with the general program of study of the endurance properties of rail steels then in progress [1, 2] as a part of

---

[1] Freeman, John R., jr., Dowdell, R. L., and Berry, W. J., Endurance and Other Properties of Rail Steel, B. S. Tech. Paper No. 363. Throughout this report the above papers are referred to as the "previous reports."

[2] Freeman, John R., jr., and Solakian, H. N., Effect of Service on Endurance Properties of Rail Steels, B. S. Jour. Research, 3 (RP 92); August, 1929.

the broader investigation seeking to determine the cause of transverse fissure failure in rails.

Tests have therefore been made on these materials using the same equipment and under the same conditions as in the tests previously reported. All tests were on specimens from new rail.

II. MATERIAL STUDIED

1. MEDIUM MANGANESE RAIL

In recent years some of the railroads in the United States have been using in increasing amounts a rail steel containing approximately 1.2 to 1.7 per cent manganese and 0.50 to 0.70 per cent carbon.[3] Rail of this approximate composition has been termed "medium manganese rail" to distinguish it from the well-known 12 to 14 per cent manganese steel rail that has been extensively used in switches, crossovers, and similar locations subject to great wear.

The medium manganese rails used in the tests reported here were made by the Bethlehem Steel Co., at Steelton, Pa., for the Delaware, Lackawanna & Western Railroad. The chemical compositions are given in Table 1 (M–1, M–2). Tests were made on A, D, and F rails, representative of two heats with slightly different manganese and carbon contents.

TABLE 1.—*Composition of rail steels studied*

Type of steel rail	Bureau of Standards designation heat No.	Manufacturers heat No.	C	Mn	P	S	Si	Mo	Zr
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Medium manganese [a]	M–1 M–2	88227 89235	0. 655 . 590	1. 53 1. 21	0. 030 . 022	0. 057 . 045	0. 29 . 21	-------- --------	-------- --------
Heat treated (30 seconds quench).[b]	H–1–A H–1–C H–1–F	86124–A–9 86124–C–3 86124–F–1	. 73	. 60	. 026	. 050	. 25	--------	--------
Heat-treated (15 seconds quench).[c]	H–2–A H–2–C H–2–F	88074–A–7 88074–C–8 88074–F–10	. 74	. 63	. 024	. 070	. 31	--------	--------
Comparison rail [d]	H–3–C H–3–F	87173–C–11 87173–F–2	. 82	. 67	. 023	. 040	. 34	--------	--------
Manganese molybdenum.[e]	E–1	-------------	. 45	1. 70	. 024	. 010	. 16	0. 38	--------
Zirconium treated medium manganese.[f]	K–1	84–J–254	. 63 [g]. 65	1. 56 [g]1. 59	. 024 [g]. 014	. 033 [g]. 032	. 32 [g]. 32	-------- --------	-------- [g]0. 09

[a] Ladle analysis, medium manganese rail steel, Bethlehem Steel Co. R. E. 130-pound section. For Delaware, Lackawanna & Western R. R.

[b] Ladle analysis, Bethlehem Steel Co. rails quenched 30 seconds in water. Heated after quenching at 950° F. for 1½ hours, then air cooled. P. S. 130-pound section. For Pennsylvania R. R.

[c] Ladle analysis, Bethlehem Steel Co. Rails quenched 15 seconds in water. Heated after quenching at 950° F. for 1½ hours, then air cooled. P. S. 130-pound section. For Pennsylvania R. R.

[d] Ladle analysis, Bethlehem Steel Co. Carbon rail steel, normal practice P. S. 130-pound section. For Pennsylvania R. R.

[e] From O position, Mn–Mo rail from Molybdenum Corporation of America.

[f] Ladle analysis, zirconium-treated medium manganese rail steel, Bethlehem Steel Co. For Boston & Maine R. R.

[g] From O position.

---

[3] Report of Committee on Rail, Bulletin, Am. Ry. Eng. Assoc., **30**, No. 315, Appendix G, March, 1929.

2. HEAT-TREATED RAILS

The heat-treated rails were made in accordance with the Kenny process.[4] The rails used for the tests reported here were, after rolling, allowed to cool until the base became slightly magnetic as determined by a magnet. The rails were then quenched in water for a predetermined number of seconds. They were then immediately transferred into a furnace preheated to 950° F., held at that temperature for one and one-half hours, then drawn out and allowed to cool in air.[5] The chemical compositions and time of quenching are also given in Table 1. (H–1 and H–2.)

For comparison with the heat-treated rails tests were also made on rails from a normal heat designated as H–3, details of which are also given in Table 1.

3. MANGANESE MOLYBDENUM RAIL

In the search for a superior rail manganese molybdenum steel has been proposed by the Molybdenum Corporation of America and service test rails are now in track.

Unfortunately details of manufacture of the rail on which tests are reported here are not available. It was an A rail and had the composition as determined by analysis from the O position, as given in Table 1.

4. ZIRCONIUM-TREATED MEDIUM MANGANESE RAIL

This rail was from a special heat of rail steel made at the Bethlehem Steel Co. for the Boston & Maine Railroad. The sample was an F rail taken from the seventh ingot of heat No. 84J254. The ingots were of 7-rail length so that the sample came from the top of the next to the last rail of the ingot. The steel was poured in the usual way into ordinary molds 25 by 30 inches at the butt, and the ingots were poured 83 inches long. The composition is given in Table 1.

III. TEST METHODS

There was some question whether the hardness of the heat-treated rails would be uniform across the section because of the well-known mass effect in quenching. It is well known that an approximate relation exists between the hardness and endurance properties of steel. Therefore, if a marked difference in hardness were present it is obvious that fatigue tests made on specimens taken across the section, as in previously reported tests, would be expected to show considerable scatter due to the difference in properties between the central and outer portions of the head of the rail.

A hardness survey was, therefore, made of all of the rails. Both Rockwell B and Brinell numbers were determined at the points indicated in Figure 1. As will be noted later no appreciable difference in hardness between center and outer portions of the heads of the heat-treated rails was apparent. The endurance test specimens were, therefore, taken from all rails in the same manner as described fully in the previous reports.

---

[4] Kenny, E. F., U. S. Patent No. 1619025, Mar. 1, 1927; and reissue No. 17240 Mar. 19, 1929.

[5] Private communication from H. B. Bent, engineer of tests, Bethlehem Steel Co., Steelton, Pa.

For convenience, the figure showing location of test specimens is repeated here. (Fig. 2.) Duplicate contiguous (end to end) specimens were taken giving a group of 12 specimens from each rail. They were taken from adjoining portions to those on which the hardness tests were made. All test sections were taken from a location at least 1 foot from the end of the rail.

All tests were made in a rotating beam type (R. R. Moore design) of endurance testing machine. At least one of each group of test specimens was subjected to 25,000,000 cycles of stress at a value just under the endurance limit. All other specimens were run at least 10,000,000 cycles if failure did not occur previously. In all cases a specimen that was run 25,000,000 cycles was restressed at a value considerably above the endurance limit to determine whether understressing had occurred.

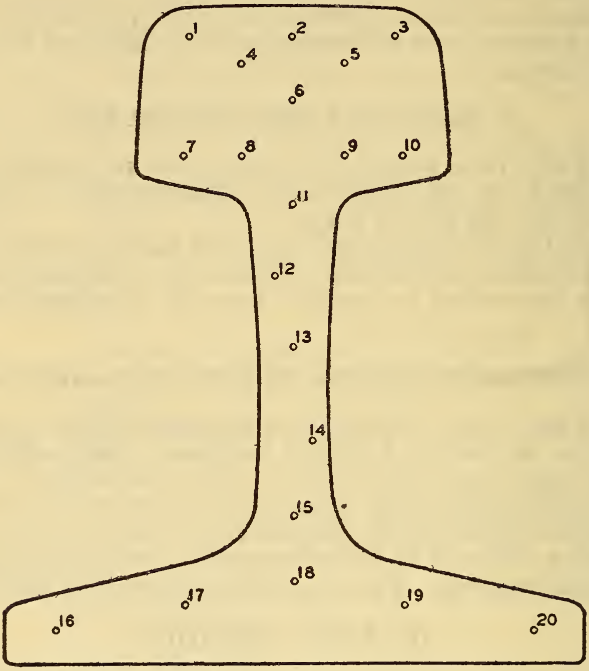


Figure 1.—*Location of Rockwell and Brinnell hardness tests*

Tensile tests were made using standard 0.505-inch diameter test bars having 2-inch gage length taken from the O position, of rails representative of all heats.

IV. RESULTS OF TESTS

1. HARDNESS SURVEY

The results of all hardness tests have been incorporated in Table 2 (*a*) and (*b*). Examination of the data shows quite definitely that there is no measurable difference in hardness between the center and outer portions of the heat-treated or other rail sections.

The maximum hardness is shown by the rails of heat H–1 which were quenched for 30 seconds. The hardness of the rails of heat H–2 which were quenched for only 15 seconds is, in general, intermediate between the untreated "normal practice" rails of heat H–3 and the rails quenched for 30 seconds (heat H–1).

There is very slight, if any, significant difference in the hardness of the medium manganese, manganese-molybdenum, zirconium-treated and normal practice carbon steel rails.

2. TENSILE TESTS

The results of tensile tests are given in Table 3. As was indicated by the hardness tests the steel from rails quenched for 30 seconds (H–1) showed the highest tensile strength. The steel from the rails quenched for 15 seconds (H–2) had appreciably lower values, but greater strength than the "normal practice" rail steel. The tensile strength of the medium manganese rail steel (M–1) containing 1.5 per cent manganese is apparently somewhat higher than that of the normal practice rail steel. On the other hand, the medium manganese rail steel containing 1.2 per cent manganese (M–2) has an indicated tensile strength appreciably lower than the normal practice rail steel and is approximately the same as that of the manganese-molybdenum rail steels. The magnitude of the difference in tensile strengths between the unheat-treated rail steels, however, is not great and might be accounted for by differences in rates of cooling particularly in the alloy steels. The total number of tests made are also too few to draw any definite conclusions.

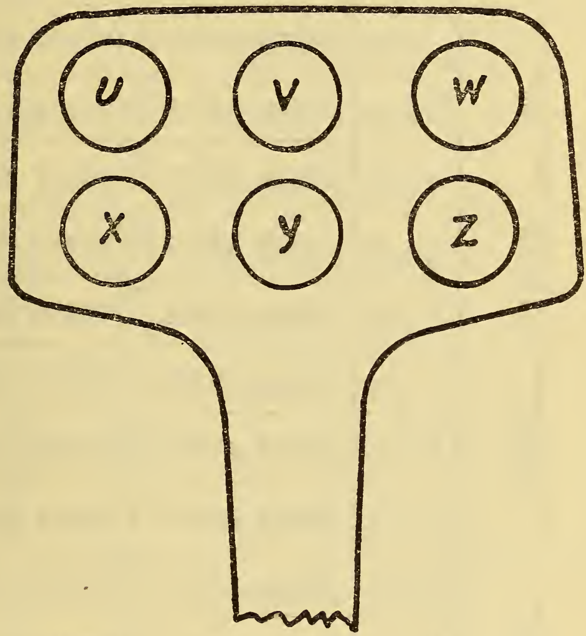


Figure 2.—*Location of endurance test specimens*

TABLE 2

(*a*) ROCKWELL B HARDNESS SURVEY OF RAIL SECTIONS

Position in section (fig. 1)	Rockwell B hardness No.															
	Heat H-1 (30 seconds quench)			Heat H-2 (15 seconds quench)			Heat H-3 (normal practice)		Heat M-1 (1.5 per cent Mn)			Heat M-2 (1.2 per cent Mn)			Heat E-1 (1.7 per cent Mn, 0.38 per cent Mo)	Heat K-1 (1.56 per cent Mn, 0.63 per cent C. Zr treated)
	Rail			Rail			Rail		Rail			Rail			Rail	Rail
	A	C	F	A	C	F	C	F	A	D	F	A	D	F	A	F
1	109	108	106	105	100	101	103	102	103	95	101	99	102	102	102	106
2	110	110	109	106	100	102	102	102	101	98	100	99	100	101	103	103
3	110	109	107	105	103	106	103	102	103	99	99	102	101	102	103	104
4	109	110	109	107	102	105	103	103	102	99	91	100	101	102	104	103
5	111	111	111	108	103	103	102	103	103	101	96	99	101	102	103	105
6	111	110	109	105	101	106	102	101	104	98	104	101	101	100	104	102
7	109	110	108	107	103	104	104	102	106	100	90	102	103	102	104	105
8	112	111	109	107	102	104	102	102	100	95	88	103	102	101	103	103
9	110	111	110	107	108	103	103	102	104	94	101	101	101	102	103	103
10	111	111	111	108	105	106	104	103	106	100	101	101	102	102	105	104
Average hardness of railhead	110.2	110.1	108.9	106.5	102.9	104	102.8	102.2	102.9	97.4	97.1	100.7	101.4	101.6	103.4	103.8
11	114	111	110	108	103	105	104	103	107	103	100	104	102	100	108	105
12	111	112	111	108	105	105	103	104	105	97	95	103	102	100	104	104
13	112	112	109	107	104	105	103	101	107	101	101	100	102	100	103	104
14	110	112	109	106	104	103	100	101	106	99	95	99	103	101	104	103
15	112	111	110	109	104	104	100	102	106	104	102	101	102	101	105	106
16	111	112	111	109	107	109	105	103	106	95	94	101	103	103	104	105
17	111	111	110	108	103	106	101	104	103	94	98	102	102	102	104	106
18	111	111	110	108	104	106	101	101	103	96	97	101	101	101	104	104
19	111	111	110	109	105	107	102	102	105	102	99	100	100	102	103	106
20	112	112	111	109	107	110	102	104	107	102	101	102	101	102	103	104
Average hardness, web and base	111.5	111.6	110.0	108.1	104.6	106.0	102.1	102.5	105.5	99.3	98.2	101.3	101.6	101.2	104.2	104.7

(b) BRINELL HARDNESS (3,000 KG LOAD) SURVEY OF RAIL SECTIONS

Position in rail (figs. 1 and 2)	Brinell hardness No.															
	Heat H-1 (30 seconds quench)			Heat H-2 (15 seconds quench)			Heat H-3 (normal practice)		Heat M-1 (1.5 per cent Mn)			Heat M-2 (1.2 per cent Mn)			Heat E-1 (1.7 per cent Mn, 0.38 per cent Mo)	Heat K-1 (1.56 per cent Mn, 0.63 per cent C. Zr treated)
	Rail			Rail			Rail		Rail			Rail			Rail	Rail
	A	C	F	A	C	F	C	F	A	D	F	A	D	F	A	F
U	363	350	341	321	311	302	285	285	282	285	269	255	255	255	269	302
V	363	352	345	306	300	302	272	285	272	262	255	244	248	252	269	285
W	359	341	341	321	319	304	285	285	293	282	269	244	252	255	266	298
X	363	354	345	321	317	306	269	285	282	269	262	252	255	255	262	293
Y	415	354	325	304	277	285	285	285	302	266	277	255	248	241	272	269
Z	361	347	341	321	317	317	283	285	282	277	269	262	262	255	272	288
Average hardness of head	370.7	349.7	339.7	315.7	306.8	302.7	279.8	285.0	285.5	273.5	265.8	252.0	253.3	252.2	268.3	292.5
11	415	359	337	341	286	302	285	269	302	272	288	266	255	241	282	277
13	388	363	341	339	302	313	285	269	306	269	288	262	262	248	269	288
15	375	350	341	341	317	321	277	272	288	269	277	255	255	241	282	272
16	383	363	352	331	321	345	302	288	302	266	272	255	255	255	262	298
20	375	361	361	321	319	341	302	298	293	277	277	266	255	248	262	293
Average hardness of web and base	387.2	359.2	346.4	334.6	313.0	324.4	290.2	281.2	298.2	270.6	280.4	260.8	256.4	246.6	271.6	286.0

TABLE 3.—*Tensile and endurance properties of rail steels studied*

Heat No.	Rail	Tensile strength	Yield point	Elongation in 2 inches	Reduction of area	Endurance limit	Endurance ratio R
		Lbs./in.²	*Lbs./in.²*	*Per cent*	*Per cent*	*Lbs./in.²*	
H-1	A	175,500		8.0	12.6	77,000	0.44
	C	167,000				[1] 68,500	.41
	F	176,000	115,000	9.5	15.2	74,000	.42
Average A, C, F rails, heat H-1.		172,833				73,166	.423
H-2	A	157,500	112,000	14.0	23.0	80,000	.51
	C	154,000	107,500	15.5	34.7	[1] 76,000	.49
	F	154,000	106,000	13.5	23.7	>67,000)	>.43)
Average A, C, F rails, heat H-2.		155,166	108,540	14.3	27.13	>74,000)	>.47)
H-3	C	139,000	91,500	11.0	15.2	59,500	.43
	F	140,000	80,000	11.0	15.2	55,500	.40
Average C and F rails, heat H-3.		139,500	85,720	11.0	15.2	57,500	.415
M-1	A	148,500	89,500	12.0	23.7	65,400	.44
	D	148,500	87,000	14.0	26.0	69,600	.47
	F	148,500		13.5	25.1	67,000	.45
Average A, D, F rails, heat M-1.		148,500		13.16	24.93	67,366	.453
M-2	A	129,500	75,000	16.0	28.8	52,800	.41
	D	135,000		14.5	28.0	55,100	.41
	F	128,500	74,500	16.0	29.8	54,800	.43
Average A, D, F rails, heat M-2.		131,000		15.5	28.87	54,233	.413
E-1	A	128,500		18.0	44.0	62,600	.49
K-1	F	145,500	90,000	16.0	34.0	65,000	.45

[1] Specimens taken as indicated in Figure 2. A difference was found in endurance limits as indicated by specimens taken from the U and Y positions, respectively.

3. ENDURANCE PROPERTIES OF MEDIUM MANGANESE RAILS

The results of the endurance tests of the medium manganese rail steels are given in Figures 3 to 8, inclusive. The data for this series and all other series are presented in the customary form of S–N diagrams as was used in the previous reports. As in the previous studies the endurance curves plotted are those obtained on the duplicate bars taken from the U, V, W, X, and Z positions in the head of the rail. The results of tests on the Y specimens, determined later, are indicated in the plot by the letter Y, beside the respective plotted values.

The endurance ratio R (ratio of endurance limit to tensile strength) is also given in the respective plots.

The results of tests on the specimens from the A rail of heat M–1 (1.5 per cent Mn) are given in Figure 3. The data indicate an endurance limit of 65,400 lbs./in.^{2} for this steel. The "scatter" is relatively very slight, indicating that the steel is relatively homogeneous across the section of the head of the rail.

The results of tests of specimens from the D rail of the same heat are given in Figure 4. An endurance limit of 69,600 lbs./in.^{2} is indicated. The scatter of results is somewhat greater than was indicated for the A rail.

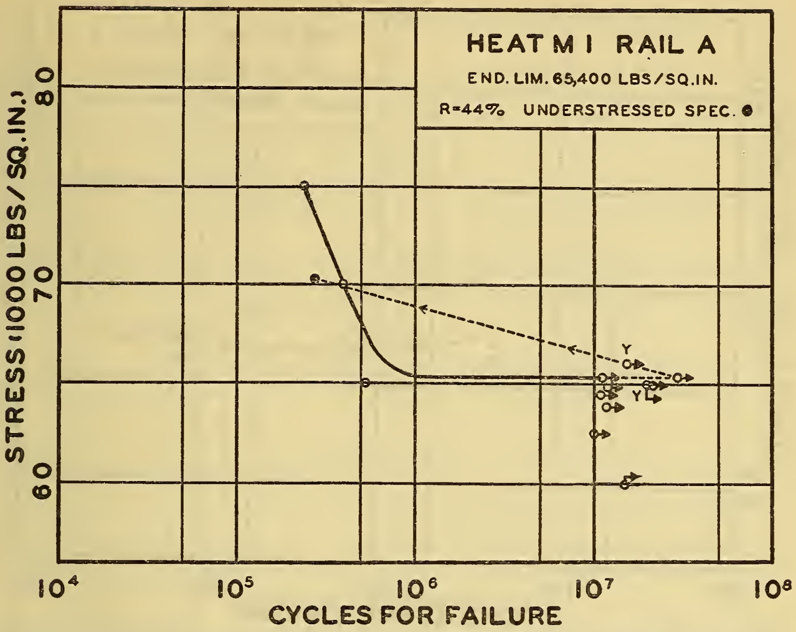


FIGURE 3.—*Endurance curve for medium manganese rail steel, A rail, heat M–1*

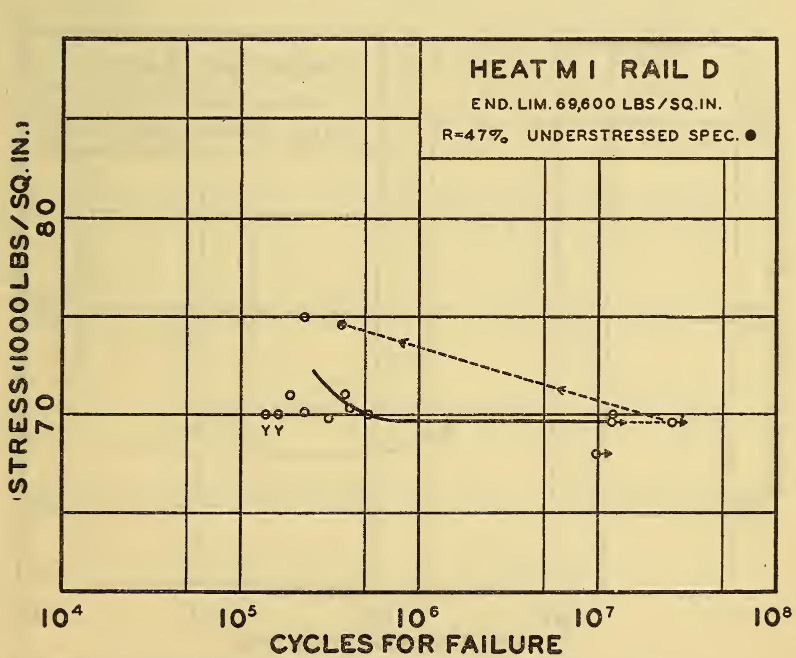


FIGURE 4.—*Endurance curve for medium manganese rail steel D rail, heat M–1*

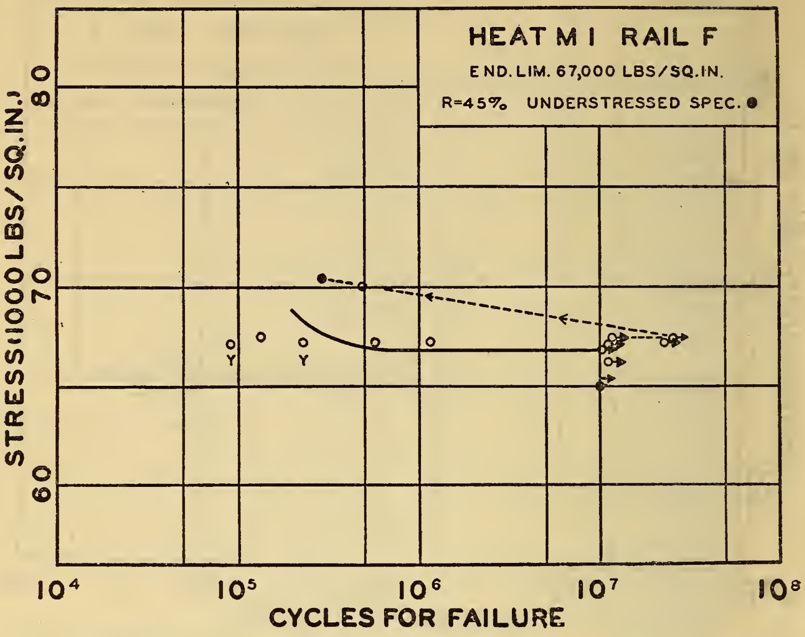


FIGURE 5.—*Endurance curve for medium manganese rail steel, F rail, heat M–1*

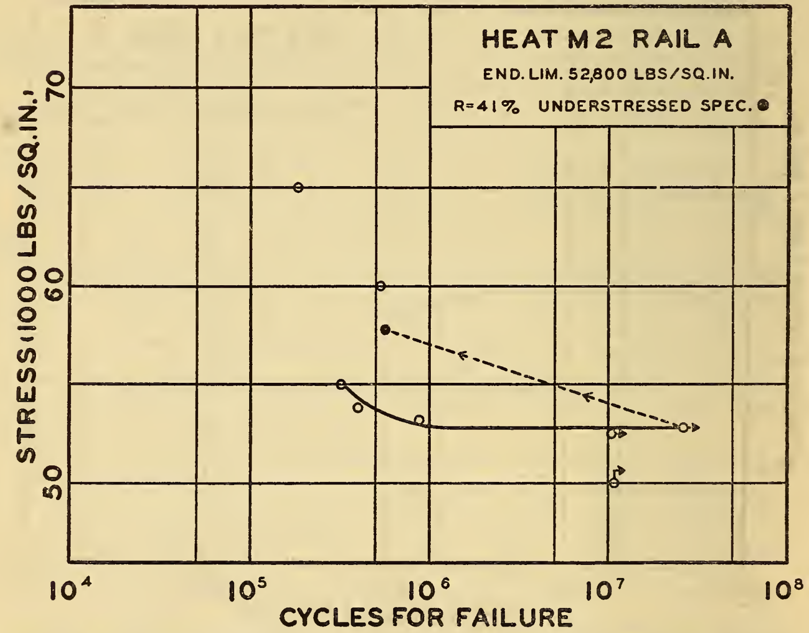


FIGURE 6.—*Endurance curve for medium manganese rail steel, A rail, heat M–2*

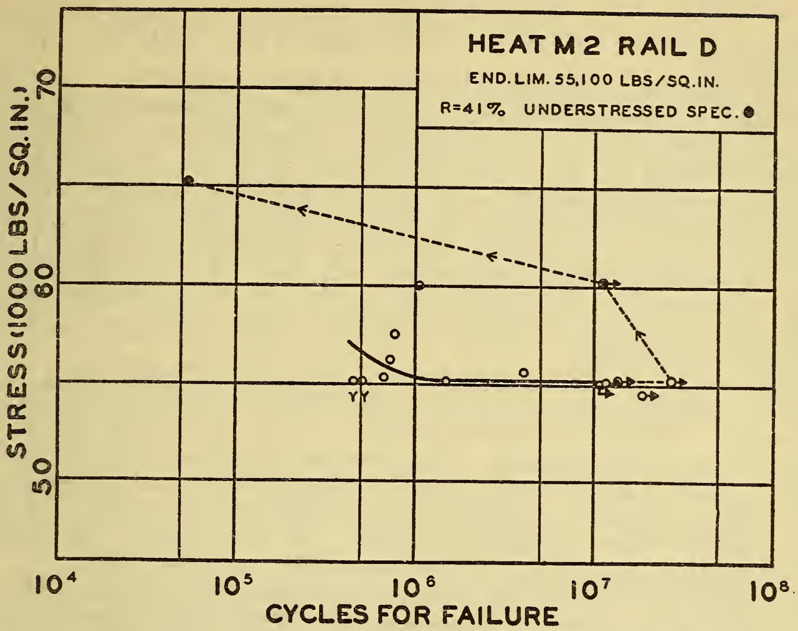


FIGURE 7.—*Endurance curve for medium manganese rail steel, D rail, heat M-2*

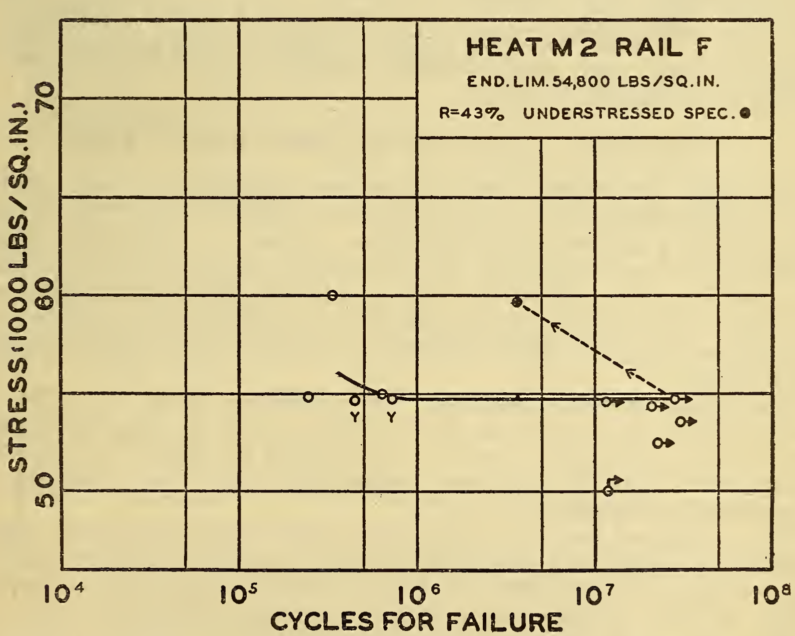


FIGURE 8.—*Endurance curve for medium manganese rail steel, F rail, heat M-2*

The results of the tests of specimens from the F rail of this same heat are given in Figure 5. An endurance limit of 67,000 lbs./in.^{2} is indicated.

The difference in endurance limits as indicated by the tests of specimens from the three rails is small. The average value is approximately 67,300 lbs./in.^{2} This value is appreciably higher than the values obtained on new or serviced carbon steel rails, the results of which are given in the previous reports with the exception of the value of 67,500 lbs./in.^{2} shown by similar tests of a transverse fissured carbon steel rail.[6] In general, the scatter of results of the data from the 1.5 per cent medium manganese rail (heat M–1) are about the same as shown by the carbon rail steels. As in the carbon steel rails the specimens from the Y position show somewhat inferior endurance properties.

The results of the endurance tests of specimens from the A, D, and F rails from heat M–2 (1.2 per cent Mn) are given in Figures 6, 7, and 8. Endurance limits of 52,800, 55,100, and 54,800 lbs./in.^{2}, respectively, were obtained. The agreement between the individual rails is good. The average value of 53,450 lbs./in.^{2} is appreciably lower than the value of 67,300 lbs./in.^{2} obtained for the steel (M–1) with slightly higher manganese content. It is well within the range of endurance properties of carbon rail steels.

It should be pointed out that the difference in endurance limits between the two medium manganese rail steels is not necessarily due to the slight difference in manganese contents and the slightly higher carbon content of the higher manganese steel. It is well known that increasing the manganese content in steels, especially with relatively high carbon content, increases the tendency toward air hardening. The difference in endurance limits of these two medium manganese rail steels may, therefore, be due in part to a difference in rate of cooling of the rails.

4. ENDURANCE PROPERTIES OF HEAT-TREATED RAILS

Although the hardness survey had not indicated any measurable differences between the outer and central portions of the rail heads from which a difference in endurance properties might have been predicted, it was recognized that the relation of hardness to endurance properties is qualitative only, and it was, therefore, considered desirable to determine experimentally if any difference in endurance properties was to be found between the central and outer portions of the head.

Two series of test specimens were therefore taken from the C rail of heats H–1, H–2, and H–3. These series of test specimens were taken contiguously (end to end) along the length of the rail from the U and Y positions, respectively, and their endurance properties determined.

The results of the endurance tests of the heat-treated and comparison rail steels may then be classified in two groups, one in which the endurance limit is determined by the results of tests of specimens taken in the usual manner across the section of the head (fig. 2) and the other as determined by specimens taken only from the U and Y positions, respectively.

---

[6] Rail from heat P. O. See p. 241 of reference 2.

The results of the former are given in Figures 9 to 16, inclusive, and of the latter in Figures 17 to 19, inclusive.

The results of tests of specimens from the A, C, and F rails of heat H–1 (30 seconds quench) are given in Figures 9, 10, and 11. The indicated endurance limits are 77,000, 68,500, and 74,000 lbs./in.^{2}, respectively. The average value is approximately 73,170 lbs./in.^{2}.

The results of tests of specimens from the A, C, and F rails of heat H–2 (15 seconds quench) are given in Figures 12, 13, and 14, respectively. The indicated endurance limits are 80,000 and 76,000 lbs./in.^{2} for the A and C rails and greater than 67,000 lbs./in.^{2} for the F rail. In the tests of the specimens from the F rail an unusually marked scatter of results was apparent. One specimen ran 25,000,000 cycles at 75,000 lbs./in.^{2} without failure. All other specimens failed at stresses above approximately 67,000 lbs./in.^{2}. Of these there were four specimens including three from the Y position which showed appreciably inferior endurance properties. This marked scatter indicated a relatively marked inhomogeneity, the cause of which was not apparent.

The results of tests of the C and F rails of the comparison heat made under normal conditions are given in Figures 15 and 16. Endurance limits of 59,500 and 55,500 lbs./in.^{2}, respectively, were found which gives an average value of 57,500 lbs./in.^{2}.

It is evident from the above data that under the same conditions of sampling and testing, the endurance limit of the heat-treated rail steels is appreciably higher than the endurance limit of the untreated "normal practice" rail steel. The endurance properties of the heat-treated rail steels in both instances are also somewhat superior to the values indicated by the tests of the medium manganese rail steels containing 1.5 per cent manganese and are markedly superior to the 1.2 per cent medium manganese rail steels.

The results of tests to determine the relative endurance properties of steel from the central and outer portions of the head of the rail from the several heats are given in Figures 17 to 19, inclusive. It is evident in comparing the data in Figures 17 (*a*) and (*b*), for the C rail from heat H–1 (quenched 30 seconds) that there is a marked difference in the endurance properties indicated by the tests of specimens from the U and Y positions. (Fig. 2.) The former has an indicated endurance limit of 79,000 lbs./in.^{2} as compared to 65,000 lbs./in.^{2} for the latter, a difference of 14,000 lbs./in.^{2}.

Similarly, the results given in Figures 18 (*a*) and (*b*), of comparative tests made of specimens from the U and Y positions of the C rail from heat H–2 (quenched 15 seconds) show the marked difference of 21,800 lbs./in.^{2}, the specimens from the U position indicating an endurance limit of 85,200 lbs./in.^{2} as compared to 63,400 lbs./in.^{2} indicated by specimens from the Y position.

That these differences in endurance properties between the outer and central portions of the head of the rail are probably related to a mass effect in the heat treatment is borne out by the results of a similar comparison of the endurance properties of the outer (U) and central (Y) portions of the head of the C rail from heat H–3 which was not heat treated but made in accordance with normal practice. The results of these tests are given in Figures 19 (*a*) and (*b*). It is evident that the respective endurance limits of 59,000 and 59,400 lbs./in.^{2} are

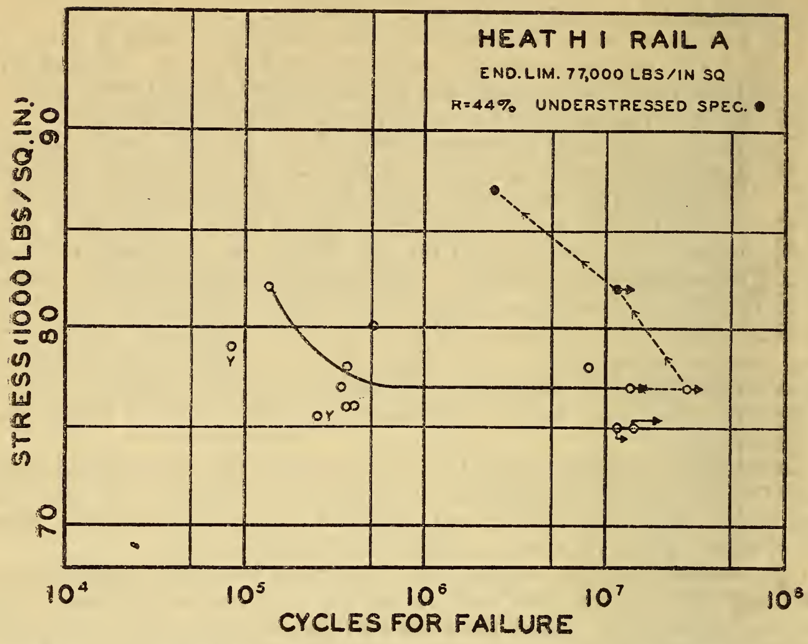


Figure 9.—*Endurance curve for heat-treated rail steel, A rail, heat H–1*

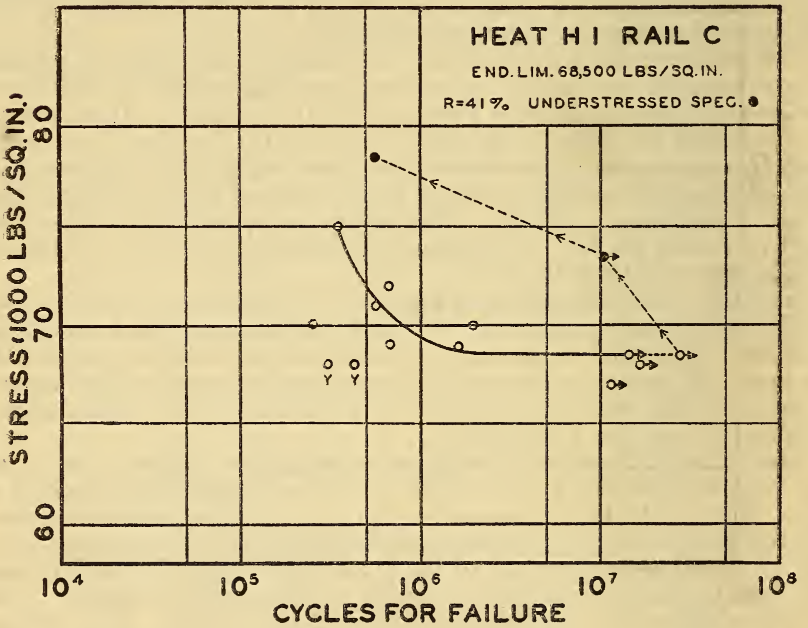


Figure 10.—*Endurance curve for heat-treated rail steel, C rail, heat H–1*

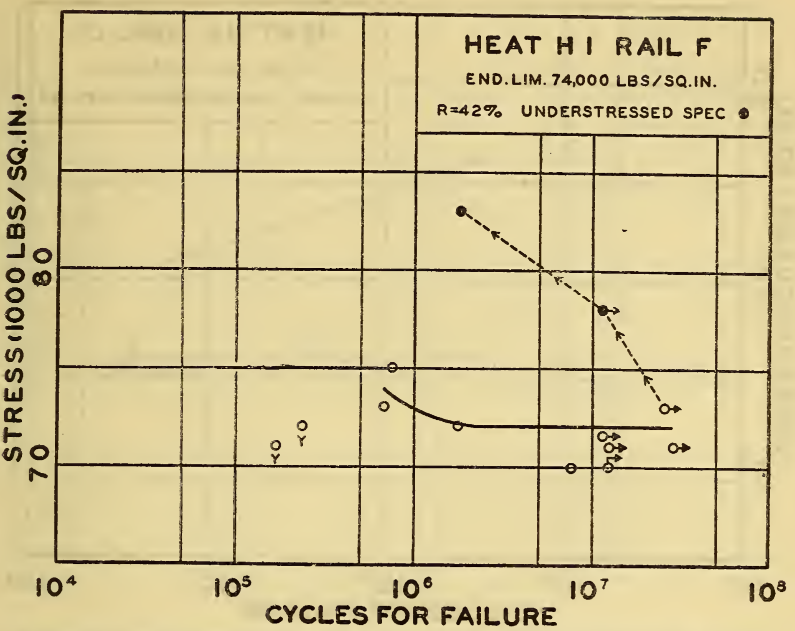


FIGURE 11.—*Endurance curve for heat-treated rail steel, F rail, heat H–1*

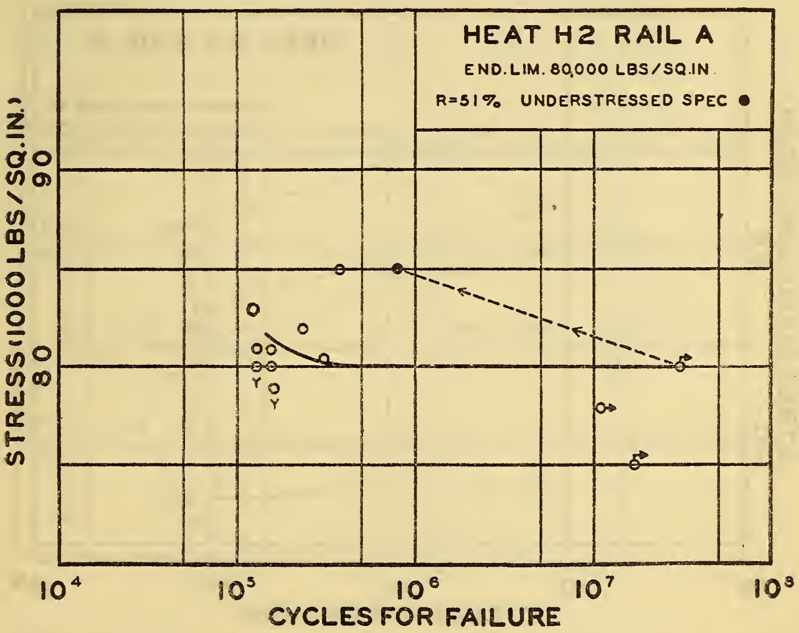


FIGURE 12.—*Endurance curve for heat-treated rail steel, A rail, heat H–2*

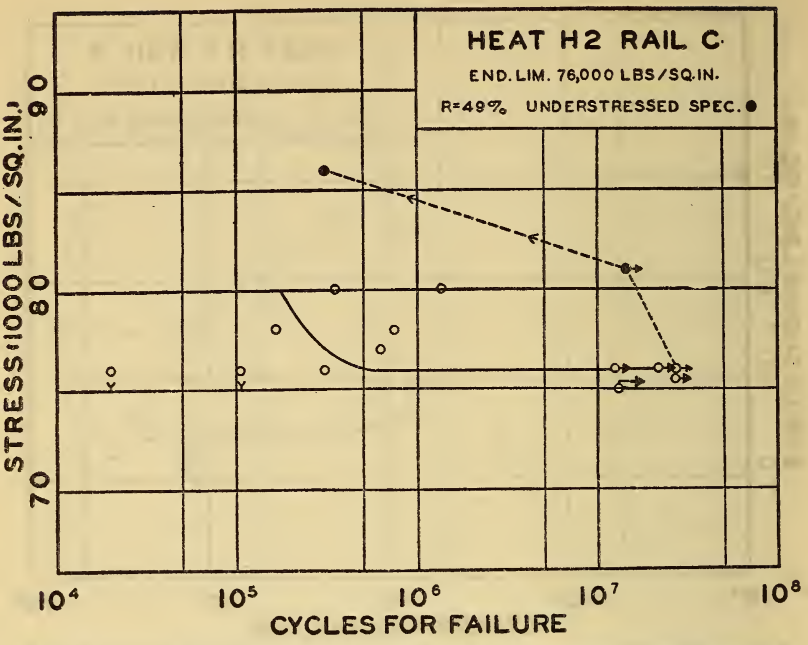


FIGURE 13.—*Endurance curve for heat-treated rail steel, C rail, heat H–2*

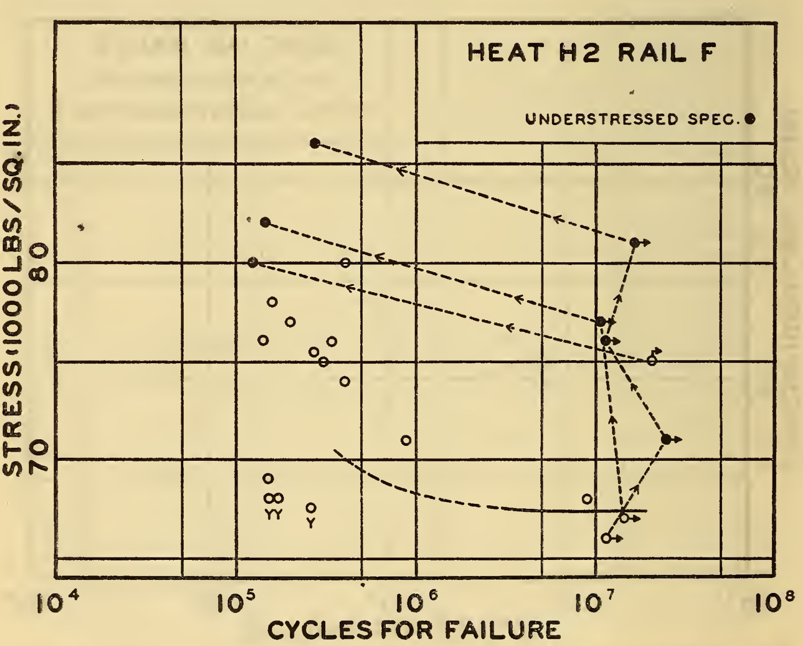


FIGURE 14.—*Endurance curve for heat-treated rail steel, F rail, heat H–2*

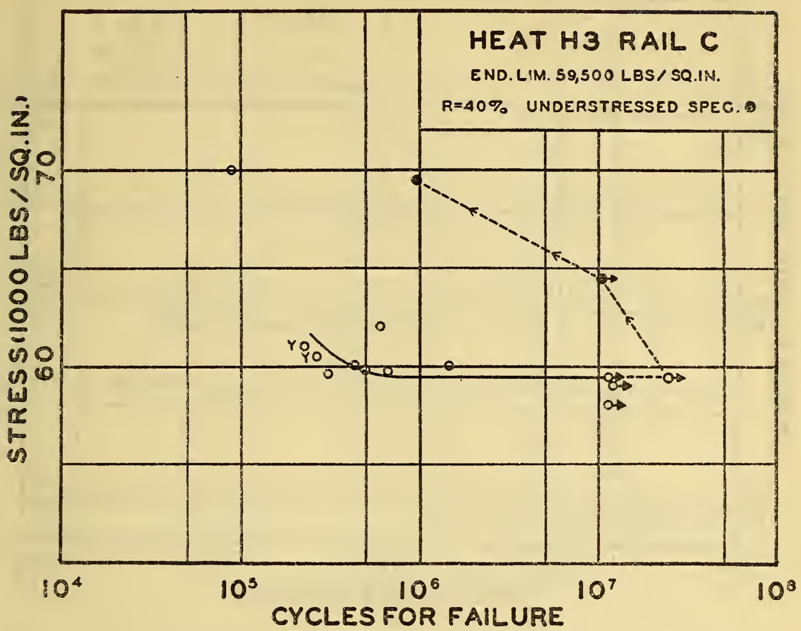


Figure 15.—*Endurance curve from "normal practice" rail, C rail, heat H–3*

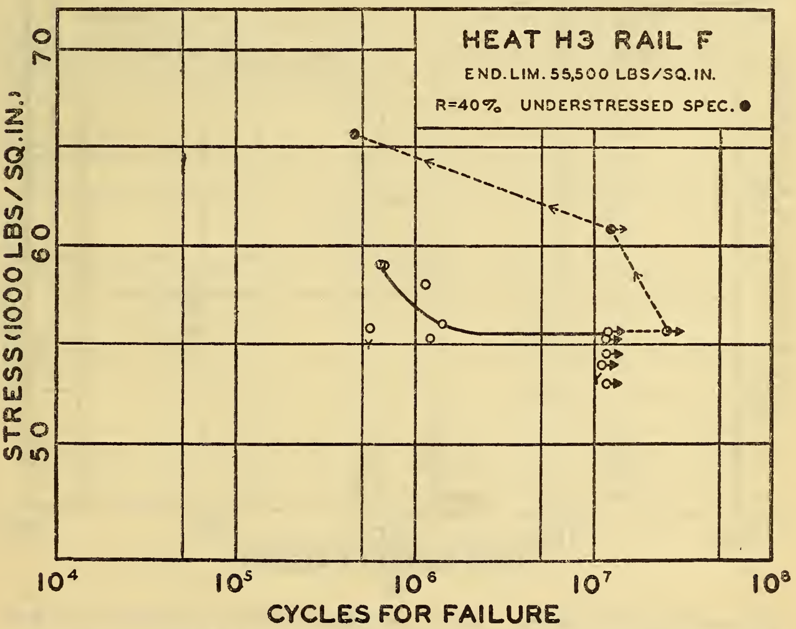


Figure 16.—*Endurance curve of "normal practice" rail, F rail, heat H–3*

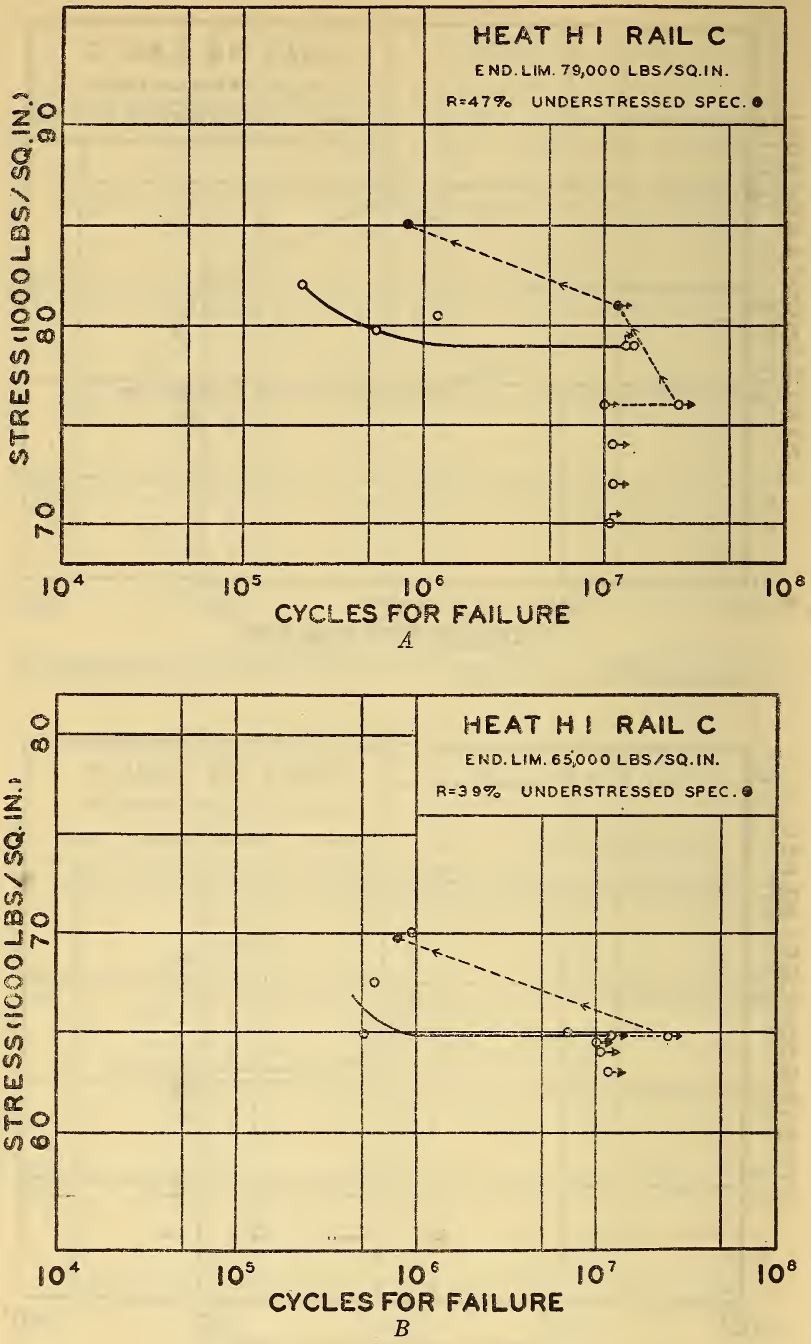
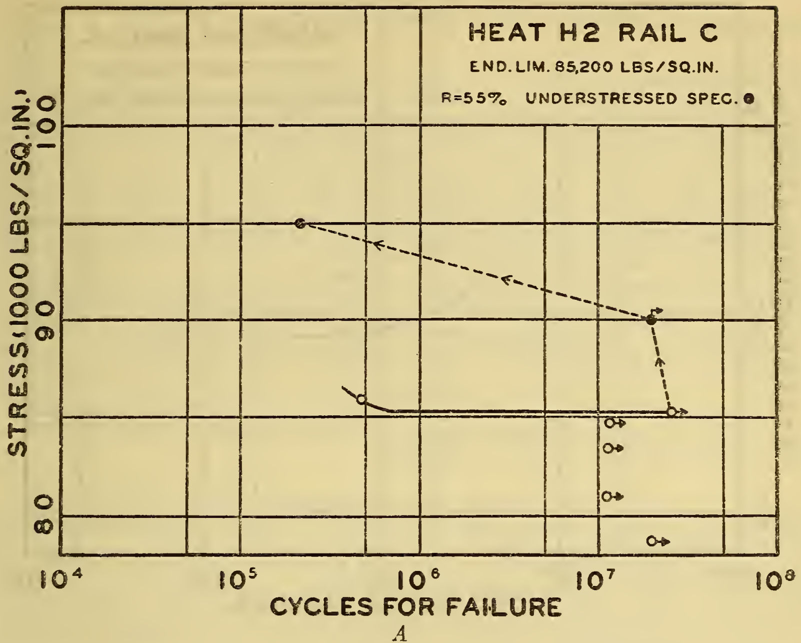
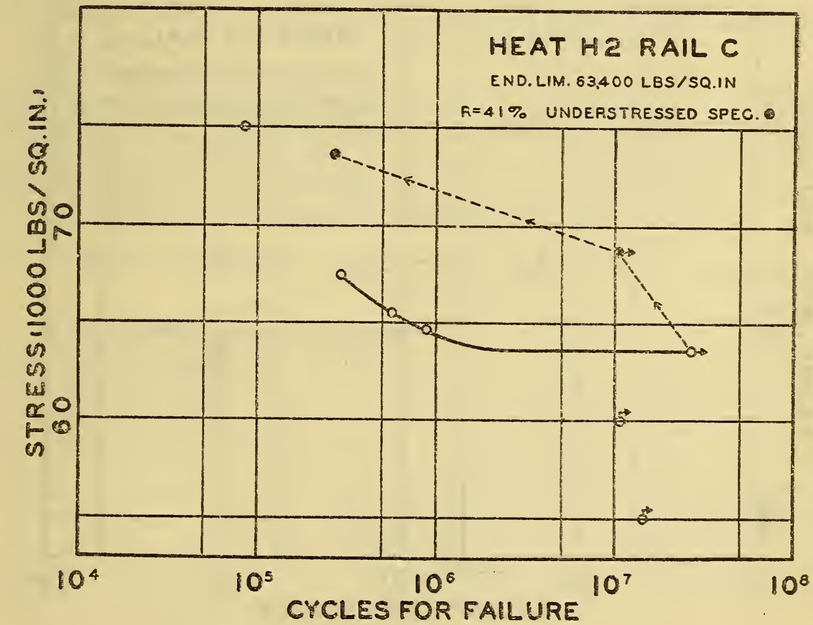


FIGURE 17.—*Endurance curves of heat-treated rail steel, C rail, heat H-1*

A, all specimens taken contiguously from U position
B, all specimens taken contiguously from Y position



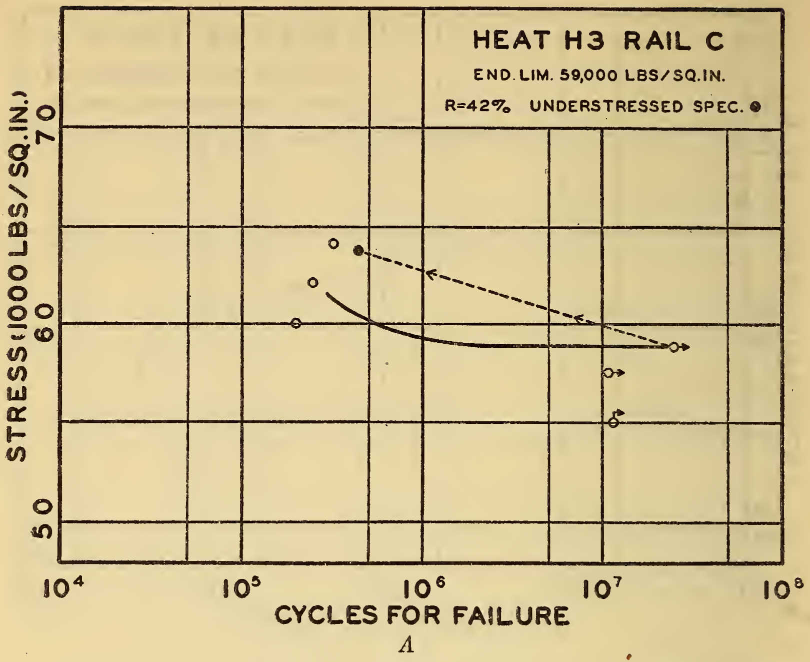
A



B

FIGURE 18.—*Endurance curves of heat-treated rail steel, C rail, heat H-2*

A, all specimens taken contiguously from the U position
B, all specimens taken contiguously from the Y position



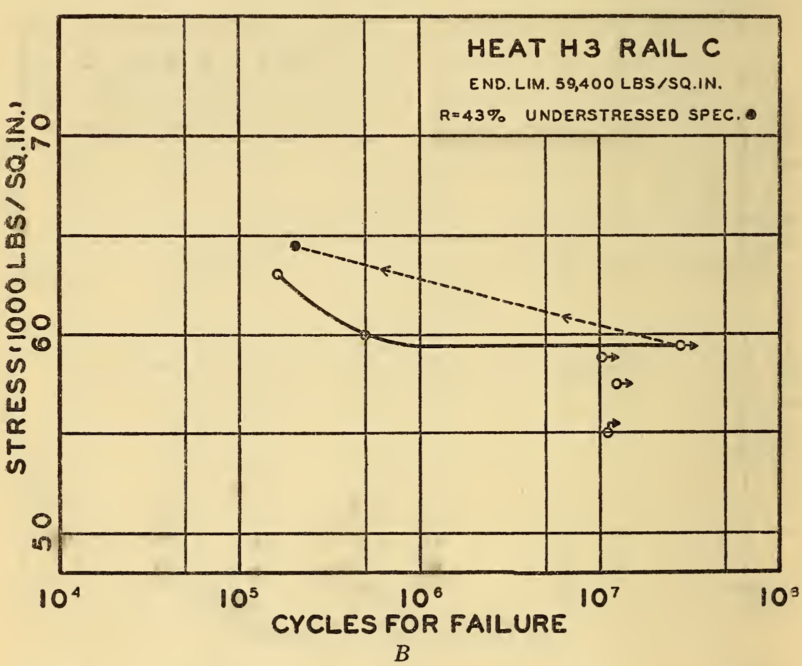


FIGURE 19.—*Endurance curves of "normal practice" rail steel, C rail, heat H–3*

A, all specimens taken contiguously from the U position
B, all specimens taken contiguously from the Y position

practically identical. Similar results were obtained in tests reported in the previous work.[7]

In making a comparison of the effect of the differences in heat treatment of the rails on the relative endurance limits obtained it should be pointed out that unfortunately the rails representative of each condition were from different heats of steel. In the previous work it was shown that the endurance properties of rail steel may vary from heat to heat[8] by as much as 13,000 lbs./in.^{2}. It is, therefore, not possible to state definitely whether the differences noted between the 30-second (H–1) and 15-second (H–2) quenched rail are a result of the difference in heat treatment or an inherent difference in the heats.

Whether the lack of uniformity of endurance properties across the section of the quenched rails is disadvantageous or possibly advantageous can not be stated without a knowledge of the distribution of stress in the head of a rail in service.

5. ENDURANCE PROPERTIES OF MANGANESE MOLYBDENUM RAIL STEEL

The results of the endurance tests of specimens from the manganese molybdenum rail are given in Figure 20. The data indicate an endurance limit of 62,600 lbs./in.^{2}. The scatter was appreciable. Further tests should be made on steel from other rails from similar heats before definite conclusions are drawn. The value indicated is slightly higher than the average found for standard practice rail.

6. ENDURANCE PROPERTIES OF A MEDIUM MANGANESE RAIL STEEL TREATED WITH ZIRCONIUM

The results of endurance tests of specimens from the F rail of a medium manganese rail steel treated with zirconium are given in Figure 21. An endurance limit of 65,000 lbs./in.^{2} is indicated. The scatter is appreciable. The endurance limit is practically the same as was found for the medium manganese rail steel (M–1) of similar composition but not treated with zirconium.

V. SOME FURTHER TESTS OF TRANSVERSE FISSURED RAILS

In one of the previous reports[9] data are given on the endurance properties of steel from transverse fissured rails. It was shown that the endurance properties of the steel in the fissured rails was equal to or greater than in similar rail which had not failed after being subjected to the same amount of service in track. These tests were made on rails removed from track on the Pennsylvania and Canadian National Railroads. Through the courtesy of J. M. R. Fairbain, chief engineer, Canadian Pacific Railway, two more rails were obtained, one of which had failed in service from a transverse fissure and the other, although subjected to identical service, had not failed. The markings on both rails indicated they were from heat No. 8501–111–08 of Dominion Iron & Steel Co.

Endurance tests were made on specimens taken from the heads of each rail in the usual manner. (Fig. 2.) The results of these

---

[7] See p. 293, fig. 21 of reference 1. [8] See p. 292 of reference No. 1. [9] See p. 237, reference 2.

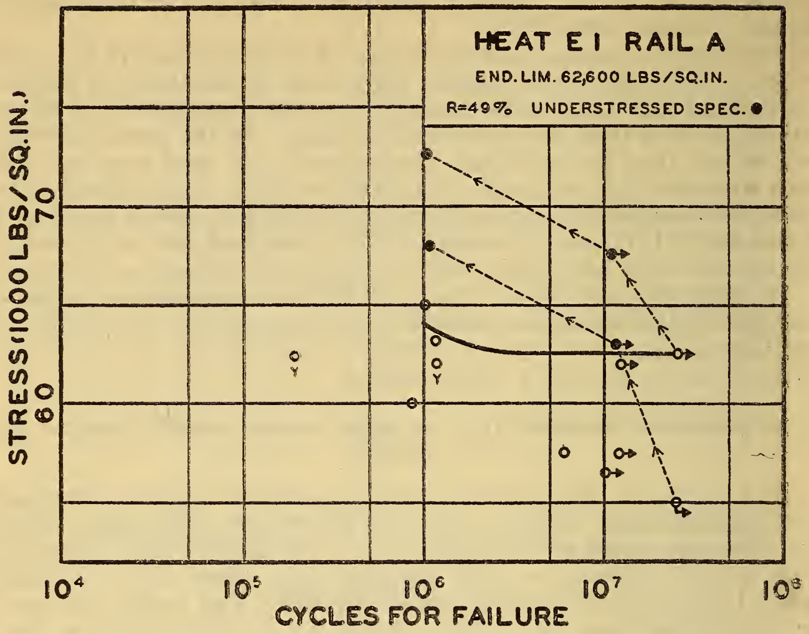


FIGURE 20.—*Endurance curve of a manganese molybdenum rail steel, A rail, heat E-1*

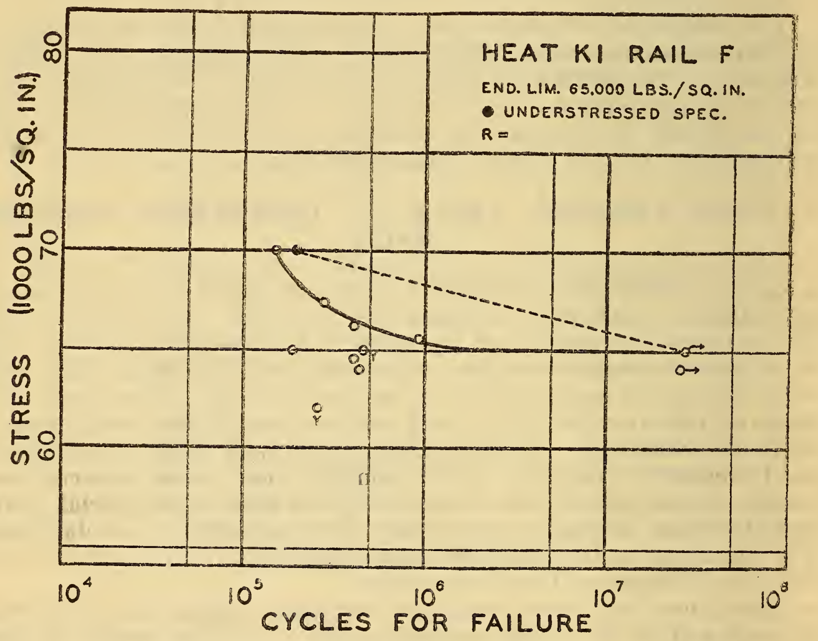


FIGURE 21.—*Endurance curve of a medium manganese rail steel treated with zirconium, F rail, heat K-1*

tests are given in Figure 22. The data indicate that the endurance limit of the steel from the fissured rail is slightly less than that from the unfissured rail. The "scatter" of results, shown by the specimens from the fissured rail is, however, quite marked. Deep etching of the test specimens showed this scatter to be due to the presence of shatter cracks in the steel, as was found in the previously reported tests of fissured rail. The specimens free from cracks indicated the endurance limit of sound portions of the steel to be well within the range of endurance limits that have been found in previous studies of rail steels that have not failed in service. These tests confirm the previous tests in showing that fatigue failure in rails (transverse fissures) probably starts from a nucleus such as a shatter crack or other similar internal defect.

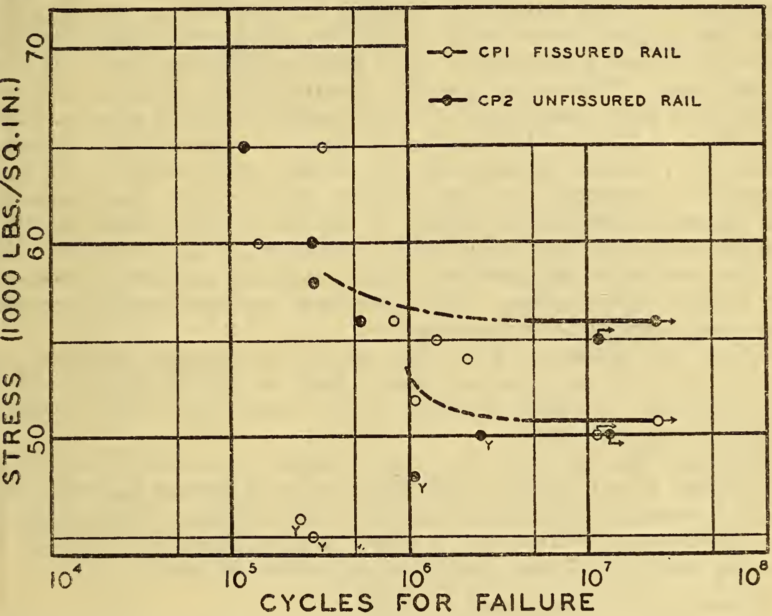


Figure 22.—*Endurance curves of steel from fissured rail* (*CP1*) *and unfissured rail* (*CP2*) *after same service*

VI. SUMMARY AND CONCLUSIONS

By request of the special joint subcommittee of the Rail Manufacturers Technical Committee and the Rail Committee of the American Railway Engineering Association a series of tests have been made to determine the endurance properties of some special heat-treated rail steels and medium manganese rail steels. Similar tests have also been made of a manganese molybdenum rail steel and a zirconium-treated medium manganese rail steel. Some further data are also given on tests of the endurance properties of steel from a transverse fissured and a comparison rail from the same heat which did not fail in service.

It has been found that the endurance properties of a rail steel may be appreciably increased by suitable heat treatment of the rail. Endurance limits of approximately 75,000 lbs./in.^{2} were obtained. It was also found that the endurance limit of the steel in the central portion of the head of a quenched rail may be appreciably less than in the outer portions of the head.

The endurance limit of a medium manganese rail steel containing 1.5 per cent manganese and 0.65 per cent carbon was found to be about 67,000 lbs./in.^{2}. Another heat containing 1.2 per cent manganese and 0.60 per cent carbon was found to have the somewhat lower endurance limit of about 55,000 lbs./in.^{2} Since the amount of manganese in this heat approximates the lower limit usually set for this type of steel the value of 55,000 lbs./in.^{2} for endurance limit indicates the lowest approximate value that may be expected in this type of rail steel. This value is within the maximum range of endurance limits that have been found to exist in the standard practice carbon rail steels. It may be concluded that, in general, the endurance limits of medium manganese rail steels, particularly with higher manganese contents, are appreciably greater than the corresponding values for carbon rail steels. It should be noted that the carbon content will also have appreciable influence on the endurance limits of the medium manganese rail steels, a higher carbon content tending to give higher values. Data, however, are not available to determine the magnitude of the effect.

Tests of specimens from one zirconium-treated medium manganese rail indicated an endurance limit of 65,000 lbs./in.^{2} for this type of steel. A value of 62,600 lbs./in.^{2} was found for a manganese molybdenum rail steel.

Data are also given in the report on the endurance properties of steel from a rail which failed by transverse fissure in track which confirm previous tests in showing that the endurance limit of the steel in a transverse fissured rail is equal to that found in rail that does not fail under the same conditions of service in track.

WASHINGTON, November 15, 1929.

(Cut here)

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

Dear Sir: Send me the Bureau of Standards publications marked X below. I inclose remittance * to cover the cost.

Mark X	Title of publication	Price		Amount inclosed
		United States, Canada, Cuba, Newfoundland, Republic of Panama	Foreign countries	
	Commercial Standards Monthly (one year)	$1. 00	$1. 25	
	Bureau of Standards Journal of Research (one year)	2. 75	3. 50	
	Technical News Bulletin (one year)	. 25	. 40	
	Standards Yearbook, 1930	. 75	1. 00	
	Total remittance			

Send to

Number and Street

City and State (or Country)

---

* Remittance should be either in the form of a post-office money order, coupons (issued for the specific purpose of purchasing Government publications), express money order, New York draft, or cash, at the senders' risk.